Scientometrics (2016) 109:1435–1454
DOI 10.1007/s11192-016-2131-y

Researchers' career transitions over the life cycle

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Received: 24 July 2015 / Published online: 3 October 2016

Abstract Based on a unique time-use survey of academic researchers in Japan, this study finds that research time decreases over the life cycle. The decrease in total hours worked and the increase in time spent on administrative tasks explain the decrease in research time. We also show that the decrease of research time partly explains why the research output of older researchers' decreases. The results suggest that proper incentives and job designs for senior researchers may increase their research output.

Keywords Researchers' time use · Research output · Academic researchers · Academic administration · Education · Multi-tasking

Introduction

The quantity of academic researchers' publications declines as they age (Diamond 1986; Levin and Stephan 1991; Oster and Hamermesh 1998; Costas et al. 2010). Many previous studies attribute this decline in the number of publications to the deterioration of mental capacity and the attenuation of incentives for tenure and promotion, because the older a researcher is, the more likely she is a tenured full professor. More recent studies, including Kyvik and Olsen (2008), find that the negative relationship between age and output has attenuated or disappeared in recent years. Stroebe (2010) emphasizes the effect of the

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period before retirement on researchers' incentives and attributes senior researchers' output slowdown to their reduced incentive, due to the shortening of the planning horizon before their retirement. Researchers' career concern is apparently an important mechanism to explain the age-output relationship, and this paper attempts to measure the changes in career stages by looking at the change in researchers' time allocation as they age.

Studies that demonstrate a link between time spent on research and research output include Taylor et al. (2006) and Barham et al. (2014). Taylor et al. (2006) illustrate that both teaching and service commitments have negative impacts on academic economists' research in the United States. Barham et al. (2014) show that an increase in time spent on administrative tasks related to grant applications results in a decrease in time spent on research and thus harms research output in the agricultural and life sciences.

An academic researcher's role typically involves three distinct academic activities: research, education, and administration.[1] As a researcher ages, the administrative obligation, both on research teams and in academic institutions, typically increases. Link et al. (2008), for example, show that promotion to a tenured position leads to less research time and more service time at top U.S. research universities. This greater amount of time spent on service leads to less time spent on research: Using data from 13 countries, Bentley and Kyvik (2013) show that time spent on research decreases as researchers age in every academic field except for the humanities.

Gingras et al. (2008) argue that the decrease in the number of first-authored papers and the increase in the number of non-first-authored papers over the life cycle suggest that senior researchers become research team managers. Using the same reasoning, Costas and Bordons (2011) also report that junior researchers in terms of age or job rank tend to be the first authors, while senior researchers tend to be the last authors. Although Costas and Bordons's innovative approach based on the order of authorship indirectly captures senior researchers' time as lab managers, it cannot capture the time spent on administrative duties that are not directly related to research but have a significant impact on the performance of researchers' academic institutions in such areas as hiring, promotion, and budget allocation decisions, among other activities. This paper contributes to the literature by adding more explicit evidence that an average researcher in Japan, like a worker in a typical workplace, experiences a career transition from player to manager in regards to research output and time use. The resulting change in time allocation—more time on administration and less time on research—explains the declining output over a typical researcher's life cycle.

According to the Survey on Full-Time Equivalents at Universities, in Japan, researchers younger than 35 work 3105 h per year, while researchers ages 45–54 work 2926 h per year, on average. Moreover, researchers younger than 35 typically spend 471 h on administrative tasks, whereas researchers 45–54 years old spend 601 h, on average. The decline in total hours worked and the change in time allocation across activities explain the seemingly smaller output of older researchers.

Career trajectory of researchers in Japan

Although details vary substantially across major fields, in Japan, there are two typical patterns of academic researchers' career trajectories. First, in the majority of natural science, medical science, and engineering fields, researchers who obtain a Ph.D. degree start

[1] Valorization of knowledge is often called as the third mission of universities. Researchers' activity that embodies the valorization mission of universities is arguably classified as dissemination of research outcomes to general public. These activities are classified as administration activity in our measurement.

their academic career as a post-doctoral researcher on a fixed term contract. Researchers' job ranks on these fixed term contracts are typically lecturer (*jokyo*), assistant (*joshu*), or post-doctoral fellow. Unlike the tenure-track system in the United States, researchers on fixed-term contracts are rarely directly promoted to a tenured position in the same department. Depending on the field of research, fixed-term positions can range from a few years to more than 10 years. This system is more prevalent in the natural science, medical science, and engineering fields, perhaps because these fields are generally collaboration-intensive.

The second pattern is prevalent in the humanities and social sciences, as well as some natural science areas. In these fields, researchers typically start their careers as a tenured assistant professor right after completing their Ph.D. program or even before finishing the dissertation. They can expect promotion to an associate professor position in several years. This rather traditional system is more prevalent in fields where the evaluation of researchers depends on long-term performance, such as publication of books, and peer reputation counts more than publication in international peer-reviewed journals. Most fields in the humanities and social sciences fall into this category. In these fields, top-ranked research universities rarely hire a tenured assistant professor. Thus, a typical researcher starts her career at an education-oriented national or private university and attempts to "move up" to a research-oriented university by publishing a book and establishing a reputation in the academic field. This traditional system of "moving up" creates a problem, in that eligible young researchers are unable to work in research-oriented environments and research-oriented departments lack the stimulus of fresh-Ph.D. academics. This becomes a serious drawback in some academic fields, such as economics, that are becoming more collaboration-intensive. To overcome this drawback, some economics departments at top-research universities are transitioning from the traditional system to the US-style tenure-track system.

In either system—engineering departments' post-doc style or humanities departments' tenured faculty style—young researchers have a strong incentive to publish papers or books to find permanent jobs or "move up." Once they find a tenured job or a position at a prestigious university, the incentive to do research is arguably weakened.

Promotion from associate professor to full professor is based on performance of research and other university duties. Promotion policies vary across departments, and there is a substantial variation in the age at which a typical researcher is promoted to a full professor, even within a particular field.

Teaching load does not vary much across job ranks among tenured positions (including tenured assistant professors), while it is typically lighter for fixed-term researchers. Regarding administrative duties, full professors typically serve in more responsible positions, such as department chair or chair of a departmental committee, than associate and assistant professors. From which rank researchers can supervise Ph.D. students also varies across fields and institutions.

In natural science, medical science, and engineering fields that require substantial manpower and laboratory equipment to pursue a research project, job rank also may affect being able to administer research projects. In some fields, the boss of a laboratory must be a full professor; in the others, associate professors can also have a laboratory. Job rank, however, is not tied to the ability to administer research projects in many fields that do not require a large research team, such as the social sciences and humanities, mathematics, and theoretical physics.

Data

We use 2008 data from the Survey on Full-Time Equivalents at Universities (hereafter the Survey on FTEs 2008) conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT); the details of the survey results are reported and discussed in Kanda and Tomizawa (2015). An original purpose of the survey was to measure full-time equivalents (FTEs) of researchers for internationally comparable statistics of Organisation of Economic Co-operation and Development (OECD) member countries.[2] The Survey on FTEs 2008 asked about the amount of time spent on various activities in fiscal year 2007 (from April 2007 to March 2008), including time spent on research (completing work and reports related to research and guidance given to Ph.D. students), education (teaching classes, preparing for classes, supervising students except for Ph.D. students, and writing textbooks), and administrative tasks (attending faculty meetings and completing other administrative operational work for the university). It also asked about "research activities in the past 3 years (November 1, 2005–October 31, 2008),"[3] such as the number of refereed academic papers or articles accepted during the period. Using this unique dataset, we analyze the relationships among a researcher's age, time-use, and quantity of research output.

"Faculty members" in this paper refer to fulltime workers whose job title is full professor, associate professor, lecturer, or assistant professor. Although the survey also includes post-doctoral fellows and doctoral students, we limit our sample to faculty members of universities, because it is difficult to measure research productivity from the past publications of post-doctoral fellows and doctoral students. The job ranks of our sample range from assistant professor (and equivalent) to full professor, and the age range is 30–60 years old as of October 31, 2008. The size of our analysis sample is 2137.

We mention a possible sample selection bias as a caveat. The original report of the Survey on Full-time Equivalents at Universities[4] states that among 3927 faculty members, 2709 gave valid responses to the Survey of FTEs, resulting in a valid response rate of 69.0 %. The response rate was as high as 80.2 % from "humanities, social science and other" fields and as low as 59.4 % from "natural science" fields. The average number of research hours among researchers in "humanities, social science and other" filed was 842, while it was 1466 in the "natural science" field. Thus there seems to be a negative correlation between the reported average research hours and the response rate. The implication of this finding on a possible sample selection bias is not straightforward, however. The negative relationship might imply that the survey failed to capture the research hours of researchers whose research hours are long, or that those natural scientists with short research hours were less likely to respond to the survey. Although the implication is not clear, we note the differential response rates to the survey across academic fields as a caveat.

[2] OECD (2002) formulates basic definitions of FTE for international comparisons. The European Commission (EC 2009) summarizes the application of FTE to European university data.

[3] One limitation of these data is that the timing of the research output and the time when the research is being conducted are not the same. Ideally, we would like to have data on the time when the research is conducted as being a few years ago and the number of outputs in subsequent years, but the order is the opposite. Yet, we believe that our results still provide good cross-sectional evidence, provided that researchers' time use or research output does not change discontinuously at a specific age.

[4] Available at http://www.mext.go.jp/b_menu/toukei/chousa06/fulltime/kekka/1284881.htm in Japanese (accessed on July 17, 2016).

Table 1 Descriptive statistics of the analysis sample, 2008, researchers in all fields

Variable	Mean	Standard deviation	% of zero
Time use (from April 2007 to March 2008)			
Annual total hours	2927	1073	2.1 %
Annual research hours	1159	793	2.9 %
Annual education hours	765	499	3.3 %
Annual administrative and other hours	552	432	7.4 %
Annual education related service hours	138	213	46.9 %
Annual research related service hours	177	264	43.6 %
Annual service hours, not related to education or research	136	456	81.2 %
Output measures (November 1, 2005–October 31, 2008)			
First-authored refereed publications in foreign language	1.6	2.7	49.0 %
Refereed publications in foreign language	7.0	9.6	25.5 %
Publications in Japanese language	5.6	9.7	21.1 %
Academic field of own major (%)			
Humanities	6.24 %		
Law and political science	2.65 %		
Economics and business	4.21 %		
Other social sciences	3.22 %		
Science—theoretical	6.20 %		
Science—experimental	15.23 %		
Engineering	18.26 %		
Agricultural science	14.10 %		
Agricultural engineering	2.41 %		
Agricultural economics	0.90 %		
Basic medicine	7.47 %		
Clinical medicine	5.91 %		
Basic dentistry	0.90 %		
Clinical dentistry	1.37 %		
Pharmaceutical sciences	2.84 %		
Other health sciences	2.79 %		
Home economics	0.61 %		
Education	2.65 %		
Art	0.61 %		
Other	1.42 %		
Rank			
Professor	40.5 %		
Associate professor	34.7 %		
Assistant professor (*kousi*)	10.5 %		
Lecturer (*jokyo*)	14.3 %		
Age	45.6	7.9	
National and public universities	55.4 %		
Research institute	4.2 %		
Fixed term contract	19.0 %		
Adjunct affiliation in other department	15.5 %		

Table 1 continued

Variable	Mean	Standard deviation	% of zero
Adjunct affiliation in other university	17.4 %		
Adjunct affiliation other than universities	16.9 %		
Foreign nationality	1.2 %		
Female	11.1 %		
Number of institutions for which the respondent has ever worked	3.0	2.5	
Doctoral degree holders	84.9 %		

Table 1 reports the descriptive statistics. Our dependent variables are time spent on different activities and research outputs. On average, researchers spend 39.5 % of their time on research, 26.2 % on education, 18.9 % on administration, and the rest on public relations and outreach activities. Although the dataset includes the hours spent on various services, as shown in Table 1, many researchers report zero for such activities. Thus, we focus on time spent on research, education, and administration and others.

Research outputs are measured in three ways to capture the different aspects of research activities: first-authored refereed publications in a foreign (non-Japanese) language; all refereed publications in a foreign language, including both first-authored and non-first-authored ones, and publications in the Japanese language. The number of first-authored articles in foreign-language, refereed journals presumably captures an original academic contribution as a main contributor, rather than as a manager of a laboratory. A researcher writes 1.6 first-authored papers during the 3-year period, on average. The total number of articles in foreign-language, refereed journals presumably captures the original academic contribution as a project member, including as the leader of a laboratory. On average, researchers write 7.0 papers in the 3-year period.

We pay particular attention to refereed publications in foreign languages, because most original academic findings in the hard sciences are published in international refereed journals. The number of publications in the Japanese language presumably captures activities that disseminate research outputs to wider audiences. Established researchers are often invited to write review articles in the Japanese language. On average, researchers write 5.6 articles in Japanese during the 3-year period.

The academic fields covered by the survey include natural science, engineering, agricultural science, medical science, humanities and social sciences, and other miscellaneous fields, such as education, home economics, and art. In the sample, 16 % of respondents are in the social sciences and humanities,[5] 21 % in natural science, 18 % in engineering, 17 % in agricultural science, 21 % in medical sciences, and 6 % in other fields. Forty percent of respondents are professors, 34 % are associate professors, and 24 % are assistant professors or the equivalent.[6] Table 1 also summarizes other explanatory variables used in the

[5] Admittedly, social sciences and humanities are quite different from natural science, medical science, or engineering fields in many respects. Thus we conduct robustness checks that exclude researchers in social sciences and humanities and confirm that the results do not change. Specific results are available upon request.

[6] Note that a full-time lecturer position in Japan is equivalent to an assistant professor position in North America.

regressions, such as job rank, age, characteristics of the institution, proportion of fixed term contracts, and other characteristics.

Age effect or cohort effect?

We attempt to determine the changes of productivity and time use over the life cycle based on a single cross-section of data that covers researchers of various ages. The maintained assumption to justify this approach is that the life-cycle pattern of a typical researcher's time use does not vary with the cohort to which she belongs.

Our major concern about the violation of this assumption is that the quality of researchers changes over time because of the expansion of graduate programs, particularly after the mid-1990s (School Basic Survey). Although whether the expansion of graduate programs increases or decreases the quality of researchers is not clear a priori, the expansion of graduate programs definitely changes the timing of the selection of researchers. When graduate programs have a small student capacity, admission to graduate programs is competitive, while a large student capacity makes job finding after completing a graduate program more competitive. Generally, the selection at a later stage of the research career is more reliable for selecting a high-ability researcher to an academic position, because a significant part of research ability is revealed during graduate education.

Thus, the fraction of Ph.D. students who land in academic positions among all students presumably captures students' competitiveness in finding an academic job. We calculate a selectivity measure defined as follows:

$$selectivity_{ic} = \frac{researchers_{ic}}{ph.d.\ program_{ic}},$$

where i is the index for research field, and c is the birth-year cohort to control for the potential change of quality of researchers across researchers' cohorts induced by the expansion of graduate-program capacity. Likewise, the relative size of the Ph.D. program compared to the population can be used as a proxy for the selection at entry into the Ph.D. program. In the calculation of this selectivity measure, we neglect the international flow of researchers; some newly minted domestic Ph.D. holders find jobs in foreign institutions, while new Ph.D. holders from foreign graduate schools find jobs in domestic institutions. We note a caveat that we implicitly assume that these two flows are balanced and cancel each other out.

In the regressions, we include the log of the number of university researchers in the same field and birth-year cohort,[7] taken from School Teachers Survey; the log of the number of doctoral students in the same field who entered the Ph.D. program in the year when the respondent was 25 years old, taken from School Basic Survey; and the log of the population of the respondent's birth-year cohort, taken from Vital Statistics.[8] None of these control variables for the cohort effects has a statistically significant effect in any of the

[7] The number of university researchers is measured as of October 1, 2007, and the publicly available tabulation of the School Basic Survey shows the numbers in 5-year age categories. Accordingly, we divide our sample into the following 8 groups: born in 1943–47, 48–52, 53–57, 58–62, 63–67, 68–72, 73–77, and 78–82.

[8] The School Teachers Survey is a national statistical survey conducted by MEXT. MEXT distributes the questionnaire to each school, including universities. The questionnaire asks about the composition of teaching staff by gender, age, and specialty. Vital statistics is a set of national statistics published by the Ministry of Health, Labour and Welfare. The data are tallied by birth and death registration.

regressions presented in the following sections, and the estimated coefficients for other variables do not change in significant ways when these variables are excluded. Although the insignificance of these variables is not definitive evidence for the absence of a cohort effect, it at least suggests that the potentially endogenous selection is not likely to bias our estimates significantly.

Aging and academic publications

Figure 1 plots the average number of publications by publication type over the age of researchers.[9] As a researcher ages, the number of first-authored refereed papers decreases, but the total number of refereed papers and the number of Japanese papers increase. The decrease in the number of first-authored papers and the increase in the total number of refereed papers represent the researcher's career transition from player to manager, as already found by Gingras et al. (2008).

We need to control for differences in the age distribution across academic fields or demographic characteristics of researchers to estimate the age-publication profile based on a single cross-section of data. To control for differences in academic fields and demographic characteristics, we model a researcher's academic output as

$$pub_{ji} = f_j(a_i) + \beta_j x_i + u_{ji}, \ldots \quad (1)$$

where pub_{ji}. is the number of publications in publication category j of individual i, which depends on the age of individual i, a_i, in a potentially non-monotonic way. Specifically, we include dummies for 5-year age categories on the right-hand side.[10] The vector of control variables x_i includes dummies for national and public universities, a dummy for research institutes without an undergraduate program, 12 category dummy variables for the major field of the department,[11] 20 dummy variables for the field of the respondent's own study,[12] the numb of institutions at which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy, and foreign nationality dummy. Equation (1) is estimated as a linear regression.[13]

A researcher's career transition is partly represented by promotions in job ranks. To quantify career progression through promotion, we also control for the researcher's job titles, approximated by the dummy variables for job rank category (reference: professor); indicators for fixed-term contract and having an adjunct affiliation to other institutes; and whether the individual researcher's field of study is the same as the major field of the department. Variables other than job rank categories are included, because these variables, together with the job rank dummies, represent the characteristics of a researcher's current job contract. These variables endogenously change as a researcher's career progresses and should be interpreted as mediation variables. Table 2 reports the regression results of the

[9] The Survey of FTEs asks the month and year of birth. We calculate age as of October 31, 2008.

[10] Appendix Tables 6 and 7 show that the results do not change much with different cutoffs of age categories.

[11] Departments include literature, law, economics, other social sciences and humanities, science, engineering, agriculture, medical and pharmacy, other healthcare-related majors, home economics, education, and other.

[12] See Table 1 for the breakdown list.

[13] Since, as shown in Table 1, many researchers report zero publications, we also estimate a Tobit model with the same set of explanatory variables. The estimated coefficients are reported in Appendix Table 8; the results are qualitatively the same.

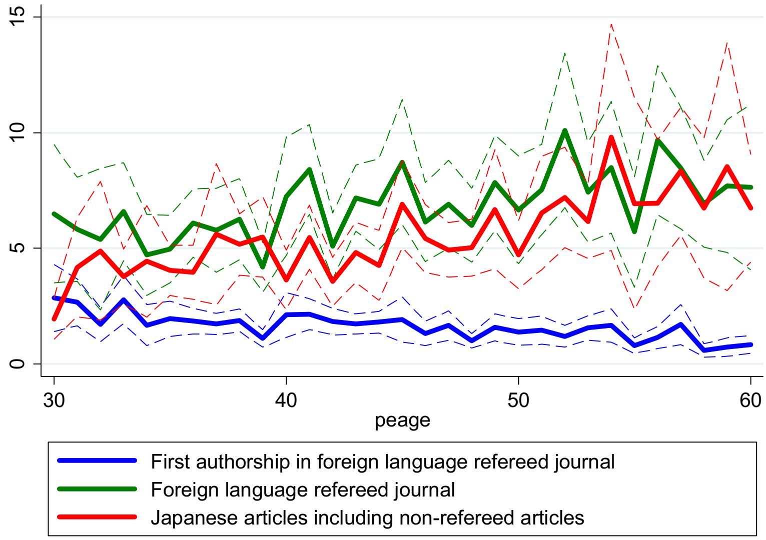

Fig. 1 Publication portfolio over age, number of publications in the last 3 years. *Note Dashed lines* are 95 % confidence intervals

number of publications on age dummy variables, with and without the controls for variables approximating a researcher's job titles. As shown in Column (1), researchers over the age of 45 publish 0.8–0.9 fewer first-authored foreign-language papers per 3 years than researchers at ages 30–34, without controlling for the job title variables. This reduction is statistically significant. Column (2) shows the results with the job title variables. Holding the job title variables constant, the reduction of publications by age becomes more significant. The difference between Columns (1) and (2) implies that senior researchers who were passed over for promotion were not productive enough for the promotion. Columns (3) and (4) indicate that the total number of foreign publications increases as a researcher ages, but the positive relationship is solely due to the researcher's career progression, as in job rank promotion, since the positive coefficients disappear once the job title variables are controlled. Columns (5) and (6) indicate that the number of Japanese publications does not depend on age in statistically significant ways, except for the increase of publications at ages 35–39 without controlling for the job title variables. Overall, we confirm that aging reduces the number of first-authored foreign-language papers, but increases the total number of foreign-language papers, partly because of the career progression approximated by the changes in job titles; this finding confirms the findings of Gingras et al. (2008) and Costas and Bordons (2011).

Aging and time use

We now turn to the analysis of time use to further shed light on an average researcher's career transition. Figure 2 shows that annual time spent on research drastically decreases during the 30 s, from about 1500 h at age 30 to about 1200 h at age 40. We observe a further reduction of the research time down to 1000 h by around age 45. In contrast, the time spent on education increases until age 40, and the time spent on administration steadily increases until the 50 s. The increase in time spent on education and

Table 2 Aging and academic publications, number of publications in the last three years

Dep. var.	(1) First authorship in foreign-language, refereed journals	(2)	(3) All articles in foreign-language refereed journals	(4)	(5) Japanese articles, including non-refereed articles	(6)
35–39	−0.472	−0.723**	1.044	−0.259	1.480*	0.738
	(0.300)	(0.317)	(0.789)	(0.828)	(0.866)	(0.903)
40–44	−0.493	−0.910**	2.293*	0.203	1.245	−0.109
	(0.344)	(0.360)	(1.231)	(1.310)	(1.048)	(1.085)
45–49	−0.866**	−1.338***	2.783*	−0.252	1.933	0.085
	(0.421)	(0.435)	(1.551)	(1.596)	(1.210)	(1.206)
50–54	−0.828**	−1.298***	3.529**	0.061	1.693	−0.401
	(0.413)	(0.433)	(1.466)	(1.511)	(1.371)	(1.364)
55–60	−0.916*	−1.335***	3.490*	−0.445	0.136	−2.207
	(0.484)	(0.514)	(1.821)	(1.833)	(1.401)	(1.411)
Job titles		X		X		X
Obs.	2114	2093	2114	2093	2114	2093
R^2	0.113	0.126	0.206	0.240	0.132	0.154

Standard errors are in parentheses. All regression models include dummy variables for 12 category dummy variables for the major field of the department and 20 dummy variables for the field of the respondent's own study, the number of institutions for which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy and foreign nationality dummy, the log of the number of university researchers and the size of Ph.D. students of the same cohort and field, and the log population of the same birth-year cohort. Columns (2), (4), and (6) also include dummies for job rank category (reference: professor), indicators for fixed-term contract, having adjunct affiliations to other institutes, and whether the individual researcher's field of study is the same as the major field of the department

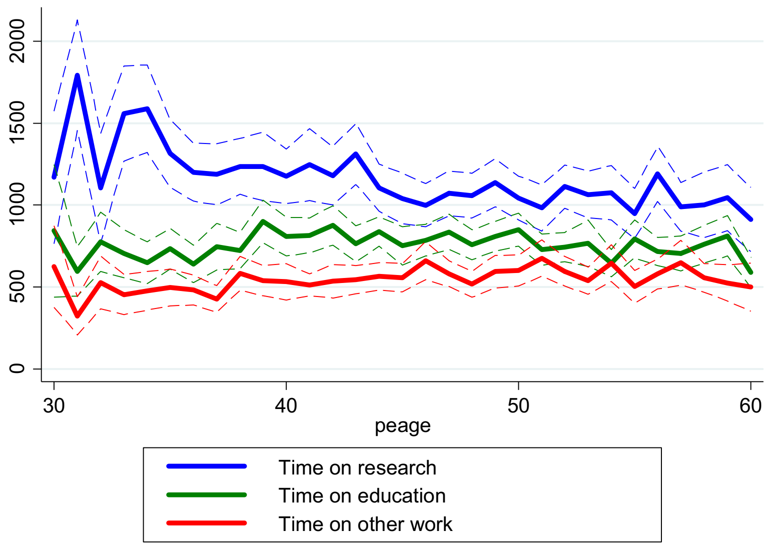

Fig. 2 Time use of researchers over age, annual hours. *Note Dashed lines* are 95 % confidence intervals

Table 3 Aging and time use, annual hours

Dep. var.	(1) Research	(2)	(3) Education	(4)	(5) Administration and other	(6)
35–39	−414.419***	−303.457***	163.608***	99.638*	118.768**	78.599
	(93.362)	(93.709)	(52.257)	(54.525)	(47.189)	(48.857)
40–44	−519.272***	−344.494***	198.321***	93.240	174.689***	103.538
	(114.286)	(115.984)	(69.117)	(72.081)	(60.766)	(64.732)
45–49	−696.595***	−512.210***	181.884**	60.554	240.901***	128.15
	(132.268)	(134.384)	(84.398)	(86.882)	(75.740)	(79.159)
50–54	−673.492***	−492.582***	145.615*	21.676	229.098***	96.346
	(133.075)	(137.353)	(86.001)	(89.622)	(77.494)	(80.944)
55–60	−589.638***	−424.076***	266.673**	165.519	113.396	−32.287
	(144.859)	(149.488)	(103.637)	(109.359)	(83.059)	(87.136)
Job titles		X		X		X
Obs.	2114	2093	2114	2093	2114	2093
R^2	0.180	0.193	0.147	0.160	0.057	0.073

Standard errors are in parentheses. All regression models include dummy variables for 12 category dummy variables for the major field of the department and 20 dummy variables for the field of the respondent's own study, the number of institutions for which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy and foreign nationality dummy, the log of the number of university researchers and the size of Ph.D. students of the same cohort and field, and the log population of the same birth-year cohort. Columns (2), (4), and (6) also include dummies for job rank category (reference: professor), indicators for fixed-term contract, having adjunct affiliations to other institutes, and whether the individual researcher's field of study is the same as the major field of the department

administration, however, is not large enough to compensate for the decrease in the time for research. Consequently, the total working hours decrease from about 3200 in the early 30 s to about 2300 in the 50 s.

To quantify the change of time allocation across activities, controlling for the heterogeneity of researchers, we estimate the same regression model as that for publications, replacing the dependent variable with the amount of time spent on each activity:

$$time_{ji} = f_j(a_i) + \beta_j x_i + u_{ji},$$

where $time_{ji}$ is the annual time use in activity j of individual i. Like the regression model for publications, we allow $time_{ji}$ to depend on the age of individual, a_i, in a potentially non-monotonic way. The vector of control variables x_i is the same as that for the regression for publications. Another specification includes the job rank dummy variables.

Table 3 Column (1) indicates that, on average, researchers at ages 35–39 spend about 414 h less on research than researchers at ages 30–34. Researchers at ages 40–44 spend 519 h less, on average, and at 45–49, they spend 697 h less. Then the research time increases slightly in the 50 s. Given that the average annual research time in the early 30 s is around 1500 h, the hours spent on research decreases significantly: The amount of the decrease is about 27 % at ages 35–39, 35 % at ages 40–44, and 46 % at ages 45–49, respectively, of the time spent on research at ages 30–34. Column (2) shows that the reduction of research time attenuates once the variables approximating researchers' job titles is controlled, implying that the reduction of research time is partly due to promotions.

The time spent on education at ages 35–39 increases by 164 h annually compared with those ages 30–34, as Column (3) indicates. The time spent on education additionally increases by 35 h at ages 40–44, but goes up and down after that and sharply increases at ages 55–60. Overall, the time spent on education is particularly short at the beginning of a career and particularly long just before and including age 60. Column (4) indicates that the inclusion of job-title dummy variables attenuates the change in time spent on education; none of the coefficients are statistically significant. Combined with the results in Column (3), the results suggest that the change of job titles, such as a promotion from assistant professor to associate professor, at around age 35 increases the time spent on education, and after the promotion, the time spent on education becomes stable, with an exceptional increase before retirement.

The time devoted to administrative and other tasks steadily increases as researchers age and peaks at ages 45–49, as reported in Column (5) of

Table 3 On average, researchers who are 45–49 years old spend 241 more hours than researchers who are 30–34 years old. This is a large increase, considering that, on average, researchers spend 550 h on administrative tasks per year. The point estimates attenuate by about 40–50 % for many age ranges and become statistically insignificant once the proxy variables for job titles are controlled for, as reported in Column (6); the increase in time spent on administrative duties is strongly associated with promotion.

Overall, the estimation results without proxy variables for job titles indicate that aging decreases the time spent on research and increases the time for administrative tasks. A 45–49 year-old researcher spends 697 h less on research and 241 h more on administration than a 30–34 year-old researcher. For any age range, about one-third of the reduction of research time is made up for by an increase in the time spent on administration. The time spent on education is almost stable over the life cycle, except for a light load at the beginning of the career. The estimation results with proxy variables for job titles implies that the career progression accounts for about one-third to one-half of the change in research hours over the life cycle; the career progression accounts for a significant part of the increase in administration hours.

The weight shift from research activity to administrative activities coincides with Link et al.'s (2008) finding that promotion to a tenured position leads to less research time and more service time at top U.S. research universities. Furthermore, the general tendency that aging reduces the time spent on research coincides with Bentley and Kyvik's (2013) finding from 13 countries.

Heterogeneous changes in time use

The aging of researchers decreases the time spent on research, on average. Is the decline because hard workers slow down or because slackers cease conducting research? Aging increases the time use for administrative tasks. Is the increase concentrated on a small number of researchers who choose a career of being an administrator, or does almost every senior researcher more or less spend their time on administrative tasks? These questions are about the heterogeneous changes of time use over the life cycle that cannot be answered by simply looking at the evolutions of average time use. To address these questions, we estimate the quantile regression models that estimate the 25th, 50th, and 75th percentiles of time-use distributions conditional on age and other demographic variables that were included in the previous regression models. Table 4 reports the estimates without controls for proxy variables for job titles, and Table 5 reports those with controls for proxy variables for job titles.

The estimation results for research time use reported in Columns (1)–(3) of Table 4 show that research time significantly declines at the 75th percentile of its distribution,

Table 4 Aging and the distribution of time use (without control for job titles), annual hours

Dep. var.	(1) Research	(2)	(3)	(4) Education	(5)	(6)	(7) Administration and other	(8)	(9)
Percentile	25	50	75	25	50	75	25	50	75
35–39	−182.443**	−316.801***	−532.763***	140.251***	135.008**	162.834**	94.122***	200.260***	190.395**
	(82.925)	(86.620)	(170.884)	(46.436)	(66.374)	(73.248)	(27.378)	(52.866)	(74.477)
40–44	−215.698	−443.457***	−842.016***	201.221***	199.040**	199.882**	179.585***	271.675***	222.576**
	(152.758)	(139.696)	(227.404)	(76.109)	(89.121)	(83.474)	(38.671)	(68.518)	(101.095)
45–49	−267.689	−565.321***	−1022.624***	174.175**	201.257*	179.873*	222.386***	292.268***	346.665**
	(168.666)	(172.929)	(270.434)	(71.376)	(107.794)	(93.308)	(51.891)	(79.739)	(140.532)
50–54	−210.865	−549.940***	−1051.012***	112.535	156.996	128.15	225.738***	295.675***	304.556**
	(164.543)	(163.984)	(244.405)	(79.847)	(110.400)	(78.959)	(45.474)	(73.733)	(130.480)
55–60	−194.504	−435.403***	−925.022***	293.117**	241.462**	260.288*	151.468**	166.129	145.778
	(152.154)	(129.921)	(269.880)	(122.073)	(116.897)	(132.984)	(69.479)	(115.281)	(179.168)
Obs.	2114	2114	2114	2114	2114	2114	2114	2114	2114
Pseudo R^2	0.094	0.110	0.128	0.121	0.100	0.087	0.043	0.051	0.046

Standard errors are in parentheses. All regression models include dummy variables for 12 category dummy variables for the major field of the department and 20 dummy variables for the field of the respondent's own study, the number of institutions for which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy and foreign nationality dummy, the log of the number of university researchers and the size of Ph.D. students of the same cohort and field, and the log population of the same birth-year cohort

Table 5 Aging and the distribution of time use (with control for job titles), annual hours

Dep. var.	(1) Research	(2)	(3)	(4) Education	(5)	(6)	(7) Administration and other	(8)	(9)
Percentile	25	50	75	25	50	75	25	50	75
35–39	−140.793*	−169.786**	−300.192**	93.372**	71.801	124.74	36.2	120.856***	120.954**
	(75.008)	(72.086)	(148.041)	(42.620)	(70.645)	(113.961)	(35.990)	(40.258)	(48.369)
40–44	−144.636	−210.267**	−381.971**	134.201*	77.116	108.503	71.477	140.775*	127.816
	(112.505)	(85.016)	(192.616)	(74.558)	(76.326)	(122.023)	(56.305)	(77.720)	(107.598)
45–49	−182.847	−326.880***	−626.783***	120.181	101.808	80.388	90.275	137.967	200.019
	(140.536)	(96.402)	(224.251)	(82.827)	(102.407)	(143.347)	(76.298)	(111.562)	(137.988)
50–54	−139.201	−310.872**	−647.137***	55.842	32.264	−2.862	83.325	104.684	106.975
	(147.257)	(131.992)	(226.147)	(95.081)	(103.330)	(139.467)	(79.592)	(109.314)	(142.096)
55–60	−169.405	−233.676	−437.866*	174.793*	78.639	139.156	21.165	0.833	-70.064
	(158.128)	(192.207)	(242.747)	(91.121)	(114.628)	(202.675)	(71.706)	(94.927)	(154.409)
Obs.	2093	2093	2093	2093	2093	2093	2093	2093	2093
Pseudo R^2	0.099	0.119	0.146	0.132	0.113	0.098	0.053	0.067	0.058

Standard errors are in parentheses. All regression models include dummy for job titles, dummy variables for 12 category dummy variables for the major field of the department and 20 dummy variables for the field of the respondent's own study, the number of institutions for which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy and foreign nationality dummy, the log of the number of university researchers and the size of Ph.D. students of the same cohort and field, the log population of the same birth-year cohort, dummies for job rank category (reference: professor), indicators for fixed-term contract, having adjunct affiliations to other institutes, and whether the individual researcher's field of study is the same as the major field of the department while the decline at the 25th percentile is limited. At the 75th percentile, the research time in the late 40 s is 1023 h less than that in the early 30 s, but at the 25th percentile it is only 268 h. This change implies that the time spent on research is very heterogeneous in the early stage of careers, but the heterogeneity decreases as the career stage progresses. The same pattern is observed with a control for proxy variables of job titles, as shown in Columns (1)–(3) of Table 5.[14] The attenuation of coefficients at the 50th and 75th percentiles implies that the decrease of research time is partly due to career progression.

The time spent on education increases by about 200 h until the early 40 s and becomes stable, regardless of the location in the distribution, as Columns (4)–(6) in Table 4 indicate. The homogeneous change of time for education implies that the time spent on education is equally distributed across researchers over all career stages. Once the proxy variables for job titles are controlled, the increase of education hours becomes statistically insignificant for most cases, as reported in Columns (4)–(6) in Table 5. This change implies that the increase of education hours as researchers age is partly due to their career progression. Columns (7)–(9) in Table 4 indicate that the time for administration increases as a researcher ages and that the increase is more significant at the upper tail of the distribution. The coefficients at the 75th percentile of the distribution are about 1.5 times larger than those at the 25th percentile at the maximum. Columns (7)–(9) of Table 5, however, show that the difference between the 75th percentile and the 25th percentile substantially decreases when proxy variables for job titles are controlled. These results imply that some researchers take extra burdens as administrators in the later stage of their careers, probably because they are promoted to positions with greater responsibility.

Overall, according to the estimation results without controlling for proxy variables for job titles, the heterogeneity of time spent on research decreases as researchers age, while the heterogeneity of time spent on administration increases slightly; the change is not as large as the decrease in the heterogeneity of time spent on research. Combined with the stable distribution of hours spent on education, the total hours worked decreases as researchers age, and it becomes homogeneous. The results with proxy variables for job titles further reveal that the decrease of research hours at the median or upper tail of the distribution is partly due to the career progression of researchers captured by the proxy variables for job titles. In contrast, the increase of administration hours is largely because of career progression.

Further evidence on career transition

We have interpreted the relationship between researchers' age and their output and time use as being a result of career transitions. We further provide two points of evidence, somewhat anecdotal rather than comprehensive, to support the hypothesis that senior researchers gradually recede from their own research and shift weight to activities that reproduce the next generation. The first evidence is on research fund-seeking activities, and the second evidence is on mentoring activities among senior researchers.

Regarding fund-seeking activities, we provide evidence that large-size research funds, such as the Grant-in-Aid for Specially Promoted Research (*Tokubetsu Suisin*) by the Japan Society for the Promotion of Science (JSPS), are typically headed by senior researchers. *Tokubetsu Suisin* is one of the largest public research funds supporting academic research in Japan. To examine the demographic characteristics of the principal investigator (PI) of each project, we downloaded the information of all 76 projects that are active as of fiscal

[14] We should note that a researcher located at a specific percentile of the research time distribution is not the researcher located at the same percentile of the other activities.

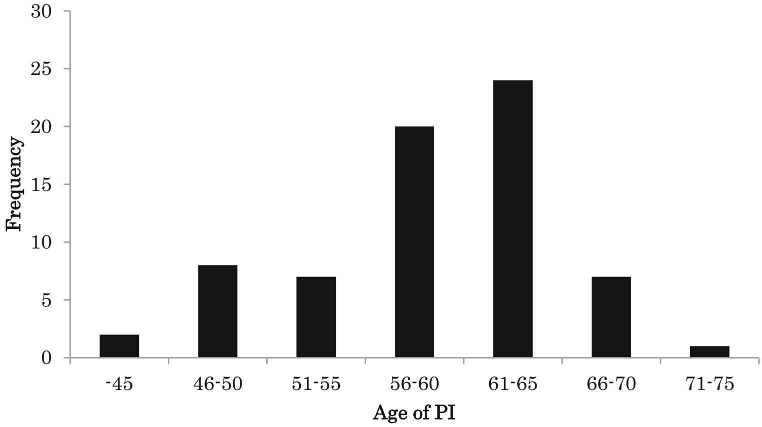

Fig. 3 Number of PIs receiving grant-in-aid for specially promoted research (*Tokubetsu Suisin*) active as of December 2015 by age groups. *Note* Data are downloaded from the KAKEN database compiled by the National Institute of Information in December 2015. The number of observations with valid PI age is 69. The mean and median of PI age are 58.8 and 60.0, respectively

year 2015 that are supported by *Tokubetsu Suishin* from the JSPS database. The downloaded data contain the name of each researcher but do not record his/her age, so we collect the age of PIs as of December 2015 or estimate it from the year of BA completion through a web search, including personal webpages, Wikipedia, and media reports. We were able to collect or estimate the age of 69 out of 76 PIs. The distribution of the PIs' ages is reported in Fig. 3. The mean and median ages of the PIs are 58.8 and 60.0, respectively, significantly older than the mean age of researchers in the analysis sample, 45.5. This is partial, admittedly not comprehensive, evidence for the claim that senior researchers are more likely to be involved in fund-acquiring activity than their younger counterparts.

Regarding Ph.D. and junior faculty advising, we take the Physics department at the University of Tokyo as an example, because it is a large department in a single field and is considered to be one of the most competitive departments in Japan. Each laboratory has a website and lists all lab members. We record the age of each PI and the number of all laboratory members, counting all the members listed on the laboratory's webpage. The correlation between the age and the size of each laboratory appears in Fig. 4. The laboratory size is relatively small when the laboratory leaders are their 40 s. The size of the laboratory becomes heterogeneous when PIs are in their 50 s, and some PIs have many junior members. This increase in the laboratory size of some researchers may well indicate that some senior researchers actively engage in mentoring activities. The size of the laboratory shrinks when the PIs enter their 60 s, perhaps because they are approaching the mandatory retirement age of 65 and start the shutting-down process by not taking any more incoming students.

Conclusion

This paper reports that as academic researchers age, they devote less time to research activities mainly because of the decrease in total hours worked and partly because of the increase in hours spent on administrative tasks. The decrease in total hours worked is a

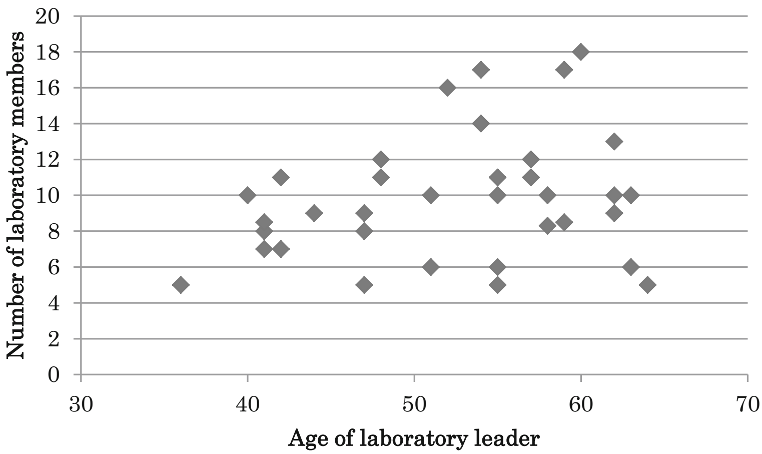

Fig. 4 Age of PI and size of laboratory at physics department of the University of Tokyo as of April 2016. *Note* Counts of laboratory members are based on each PI's webpage. Some laboratories have more than one PI. In such cases, the number of laboratory members is prorated

natural consequence of academic researchers' life-time career concerns. Young researchers work hard to accumulate academic skills and secure a permanent academic position through publishing research outputs. Thus promotion to full professor significantly diminishes the incentive to work long hours. Although the lack of family background information in our survey data prohibits us from making a definitive argument, the increase of family commitment, such as that arising from parenthood, arguably explains the decrease of total working hours as well.

The decrease of research hours over researchers' careers makes a stark contrast to the constancy of hours devoted to education and the slight increase of hours devoted to administrative tasks. This contrast could also well be explained by incentive structures set by academic institutions in Japan. Typically, departments in Japan assign mandatory teaching loads and committee tasks in an egalitarian way, regardless of researchers' research outputs. If a researcher seeks a teaching load reduction or an exemption from administrative tasks, she basically needs to exercise an "exit" option to move up to a higher-quality institution that offers a better package of teaching load and administrative tasks, but exercising this "exit" option is sometimes costly because of family and other reasons. Thus, egalitarian task assignment rules explain the combination of the decrease in research time and the constancy of education and the increase of administration time.

The reallocation of time from research to administrative tasks is also a natural consequence of a promotion from being one of many players to leading a team at various levels. The decrease in time devoted to academic research explains a substantial part of senior researchers' decline in research output. These findings from Japanese academics reconfirm findings from other countries about the career transitions of researchers measured by the order of authorship or time use (see Gingras et al. (2008), Costas and Bordons (2011) for the authorship order; Link et al. (2008) and Bentley and Kyvik (2013) for time use).

Our findings imply that a decrease in physical and mental abilities is not the sole explanation for senior researchers' decline in research output. Therefore, there is room to improve senior researchers' output by offering a better incentive scheme to induce them to expend more effort on research. In designing research incentives for senior researchers, we should pay careful attention to the fact that the power incentive in a multi-task environment generally distorts the effort allocation across tasks. The power incentive given to the research output of senior researchers, however, would not crowd out such activities as research fundraising and mentoring junior researchers, because these activities are complementary to research activity, as funding agencies tend to fund large-scale projects based on the PI's research achievement and large-scale projects tend to involve a large number of researchers involving mentoring junior researchers. The power incentive, in contrast, may crowd out educational activities, because education, particularly undergraduate education, is not necessarily complementary with research activities; one could be a very effective undergraduate instructor without being a good researcher (Hattie and Marsh 1996). Thus proper incentives should be given to educational activities to counter a possible crowding out caused by the research incentive given to senior researchers. An incentive design that induces specialization in either research or education among senior academics would be a viable option.

Acknowledgments This research was initially conducted as a part of a project by the National Institute of Science and Technology Policy (NISTEP). Akiko Togawa provided excellent research assistance, and Kensuke Kobayashi offered helpful comments. Financial support from the JSPS KAKENHI Grants (15K17072 and 16H03630) is gratefully acknowledged.

Appendix

See Tables 6, 7 and 8.

Table 6 Aging and academic publications with different cut-off values for the age groups

Dep. var.	(1) First authorship in foreign-language, refereed journals	(2)	(3) All articles in foreign-language refereed journals	(4)	(5) Japanese articles, including non-refereed articles	(6)
33–37	−0.288	−0.492	0.300	−0.883	1.166	0.442
	(0.344)	(0.337)	(0.931)	(0.956)	(1.030)	(1.036)
38–42	−0.568*	−0.980***	1.312	−0.893	1.166	−0.412
	(0.345)	(0.343)	(1.097)	(1.143)	(1.112)	(1.209)
43–47	−0.832*	−1.300***	2.037	−1.108	1.15	−0.901
	(0.425)	(0.430)	(1.296)	(1.337)	(1.250)	(1.325)
48–52	−1.208***	−1.709***	2.456*	−1.315	1.25	−1.161
	(0.446)	(0.463)	(1.426)	(1.457)	(1.322)	(1.400)
53–57	−0.942**	−1.464***	2.724*	−1.413	1.672	−0.881
	(0.460)	(0.475)	(1.581)	(1.607)	(1.514)	(1.575)
58–64	−1.418***	−1.974***	1.954	−2.466	0.734	−1.884
	(0.505)	(0.525)	(1.860)	(1.881)	(1.773)	(1.846)
Job title		X		X		X
Obs.	2137	2116	2137	2116	2137	2116
R^2	0.113	0.126	0.207	0.241	0.132	0.154

Standard errors are in parentheses. All regression models include dummy variables for 12 category dummy variables for the major field of the department and 20 dummy variables for the field of the respondent's own study, the number of institutions for which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy and foreign nationality dummy, the log of the number of university researchers and the size of Ph.D. students of the same cohort and field, and the log population of the same birth-year cohort

Table 7 Aging and time use with different cut-off values for the age groups

Dep. var.	(1) Research	(2)	(3) Education	(4)	(5) Administration and other	(6)
33–37	−124.189 (116.297)	−21.134 (114.276)	52.738 (64.192)	−3.522 (63.080)	85.639 (54.784)	59.595 (55.374)
38–42	−231.649* (125.086)	−31.159 (124.529)	193.710*** (70.145)	94.735 (70.834)	191.444*** (61.898)	136.395** (63.888)
43–47	−320.655** (142.754)	−81.88 (143.890)	186.057** (80.670)	75.035 (82.698)	254.522*** (73.618)	167.043** (75.164)
48–52	−358.878** (153.310)	−123.937 (156.375)	170.123* (89.267)	47.988 (91.594)	249.513*** (80.879)	129.573 (82.423)
53–57	−332.100** (154.702)	−84.428 (158.411)	130.5 (93.767)	7.237 (97.286)	201.187** (83.531)	63.115 (85.328)
58–64	−389.185** (172.707)	−155.69 (175.000)	166.977 (105.650)	49.555 (109.005)	118.678 (95.424)	−20.597 (96.125)
Job title		X		X		X
Obs.	2137	2116	2137	2116	2137	2116
R^2	0.180	0.195	0.146	0.160	0.059	0.073

Standard errors are in parentheses. All regression models include dummy variables for 12 category dummy variables for the major field of the department and 20 dummy variables for the field of the respondent's own study, the number of institutions for which the respondent has ever worked, whether the respondent has a doctoral degree, female dummy and foreign nationality dummy, the log of the number of university researchers and the size of Ph.D. students of the same cohort and field, and the log population of the same birth-year cohort

Table 8 Aging and academic publications: tobit model

Dep. var.	(1) First authorship in foreign-language, refereed journals	(2)	(3) All articles in foreign-language refereed journals	(4)	(5) Japanese articles, including non-refereed articles	(6)
35–39	−0.531 (0.462)	−0.841* (0.486)	1.061 (1.048)	−0.386 (1.094)	3.038*** (1.151)	1.764 (1.177)
40–44	−0.738 (0.590)	−1.273** (0.620)	2.142 (1.632)	−0.212 (1.724)	2.440* (1.407)	0.34 (1.431)
45–49	−1.510** (0.742)	−2.117*** (0.768)	2.507 (2.042)	−1.106 (2.107)	3.176* (1.624)	0.342 (1.615)
50–54	−1.486** (0.742)	−2.084*** (0.780)	3.09 (1.960)	−1.174 (2.023)	3.178* (1.759)	−0.038 (1.740)
55–59	−2.185*** (0.830)	−2.716*** (0.873)	2.059 (2.342)	−2.805 (2.371)	1.832 (1.804)	−1.562 (1.809)
60–64	−1.987* (1.039)	−2.664** (1.075)	1.061 (1.048)	−0.386 (1.094)	3.038*** (1.151)	1.764 (1.177)
Job title		X		X		X
Obs.	2137	2116	2137	2116	2137	2116

Standard errors are in parentheses. This is a tobit version of Table 2; the same notes apply to this table

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